Journal of the Palaeontological Society of India
Volume 62(1), June 30, 2017: 17-30

ISSN 0552-9360

OCCURRENCE OF FOSSIL WOODS IN THE UNAKOTI DISTRICT, TRIPURA AND THEIR PALAEOCLIMATIC SIGNIFICANCE

R. C. MEHROTRA*, NIVEDITA MEHROTRA, GAURAV SRIVASTAVA and **S. K. SHAH**

BIRBAL SAHNI INSTITUTE OF PALAEOSCIENCES, 53 UNIVERSITY ROAD, LUCKNOW-226007, INDIA
*CORRESPONDING AUTHOR E-MAIL: rcmehrotra@yahoo.com

ABSTRACT

The state of Tripura is inadequately explored as far as the plant remains are concerned. Hence, a fieldwork was undertaken to explore its northern part for building the palaeofloristics and palaeoclimate of the region, and a good number of fossil woods were collected from the Tipam Group (late Miocene) of Laljuri situated near Kumarghat in Unakoti District. They belong to *Kayea* of the Calophyllaceae, *Dipterocarpus* and *Shorea* of the Dipterocarpaceae, and *Cynometra* and *Millettia* of the Fabaceae. Their presence in the flora indicates tropical warm and humid conditions in Tripura during deposition. As all the fossils in the present assemblage are diffuse porous, they indicate tropical conditions with little seasonality.

Keywords: Fossil wood, late Miocene, northeast India, palaeoclimate

INTRODUCTION

Tripura is one of the seven sister states of India and lies in the northeastern part. The state is inadequately explored as far as the plant remains are concerned. However, some fossil woods had been described from there, especially from its western and southern parts (Ghosh and Kazmi, 1961; Mehrotra *et al.*, 2006). A fieldwork was undertaken in 2013 to explore its northern part for building the palaeofloristics and palaeoclimate of the region. A number of fossil woods were collected from a new locality Laljuri (24.1038° N; 91.9447° E) situated near Kumarghat in Unakoti District, Tripura. The geological succession of Tripura (Table 1) was discussed in detail by Karunakaran (1974). Fossil woods are generally found in the Champanagar Formation of the Tipam Group considered to be of late Miocene in age (Karunakaran, 1974).

Ghosh and Taneja (1961) described a fossil wood of *Glutoxylon burmense* (Holden) Chowdhury resembling *Gluta* of the Anacardiaceae for the first time from the Miocene sediments of Tripura. Since then some more woods had been described from there and are enlisted in Table 2.

MATERIAL AND METHODS

The fossil locality, Laljuri, is situated near Kumarghat (Fig. 1) in Unakoti District of northern Tripura. The woods are silicified and found scattered on the ground. Fifteen wood samples were collected and most of them were well preserved. They were sectioned in three planes, namely transverse (TS), tangential longitudinal (TLS) and radial longitudinal (RLS) and their ground thin sections were prepared by the grinding machine using different grades of carborundum powder. These sections were mounted in canada balsam and polished. The polished sections were studied under a high power microscope.

The slides are housed in the repository of the Birbal Sahni Institute of Palaeosciences, Lucknow. The terminology used in describing the wood fossils is after Wheeler *et al.* (1986) and IAWA (1989).

SYSTEMATIC DESCRIPTION

Family **Calophyllaceae** Agardh, 1858
Genus ***Kayeoxylon*** Chowdhury and Tandon, 1949

Kayeoxylon assamicum Chowdhury and Tandon, 1949
(Pl. I, figs. A-F)

*Description***:** Wood diffuse porous. Growth rings indistinct. Vessels round to oval, mostly small to medium, t.d. 32–144 µm, r.d. 74–187 µm, exclusively solitary, occasionally in oblique pattern, evenly distributed, sometimes tylosed, 17–27 per sq mm; vessel elements 78–128 µm in length with horizontal to oblique ends; perforation plates simple. Vasicentric tracheids poorly preserved. Axial parenchyma apotracheal banded, bands mostly continuous, sometimes broken, wavy, up to 10 cells wide, band width 179–288 µm, regularly placed; cells 9–10 µm in width and 18–26 µm in length. Rays 10–12 per mm, 1–3 seriate; uniseriates made of upright cells only, 5–18 cells or 133–354 µm high, 15–18 µm in width, multiseriates made up of procumbent cell with extensions of 1–6 rows of upright/square cells, 17–23 cells or 308–338 µm in height, 24–39 µm in width; ray tissue heterogeneous; procumbent cells 8–16 µm in tangential height and 27–50 µm in radial length; upright/square cells 18–22 µm in tangential height and 20–22 µm in radial length. Fibres moderately thick walled, polygonal in cross section, non septate, 6–11 µm in width; interfibre pits not observed. Ripple marks absent.

Horizon: Tipam Group.

Locality: Laljuri near Kumarghat, Unakoti District, Tripura.

Age: Late Miocene.

Figured specimen: Specimen No. BSIP40422.

*Affinities***:** The diagnostic features of the fossil wood viz., diffuse porous wood, apotracheal banded axial parenchyma, solitary vessels arranged occasionally in oblique pattern, vasicentric tracheids and non septate fibres indicate its affinities with the family Clusiaceae (Pearson and Brown, 1932; Kribs, 1959; Miles, 1978; Ilic, 1991). Moreover, Chowdhury and Ghosh (1946) prepared a list of taxa having diffuse porous

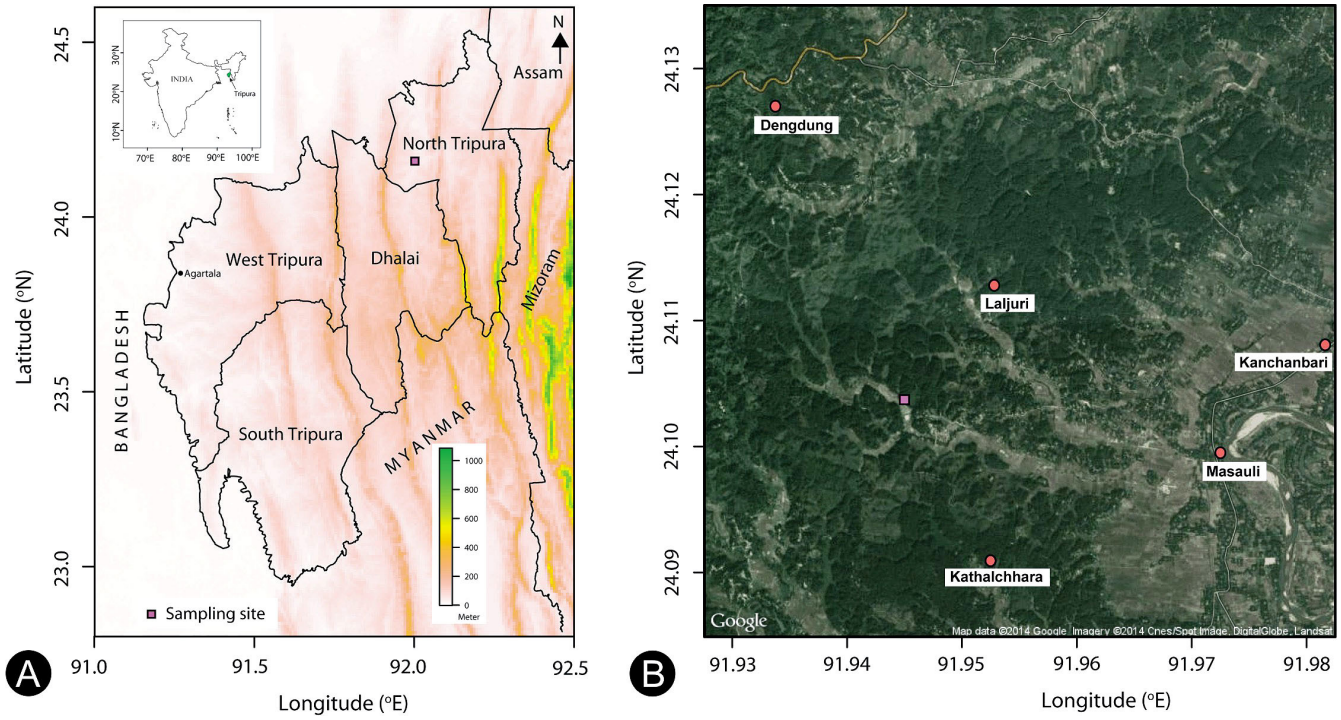


Fig. 1. Fossil locality (A) Digital Elevation Model (B) High resolution Google Map.

woods with concentric bands of parenchyma and fibres. Chowdhury and Tandon (1949) not only updated this list but also concluded that only *Kayea* Wallich of the Clusiaceae (now under Calophyllaceae) has the tendency to form oblique radial pattern. In view of the above mentioned facts the present fossil shows maximum similarities with *Kayea*. The other closely allied genera *Calophyllum* L. and *Mesua* L. have larger vessels with more pronounced oblique pattern (Tandon and Purkayastha, 1958). Tandon and Purkayastha (1958) studied woods of three species of *Kayea*, namely *K. assamica* King and Prain*, K. kunsteleri* King and *K. nervosa* T. And. and found all of them anatomically indistinguishable. Wood slides of only *K. assamic*a are available for comparison and our fossil shows close resemblance with it.

Chowdhury and Tandon (1949) instituted the genus *Kayeoxylon* to include fossil woods showing close affinities with *Kayea*. The only species of the fossil genus known so far is *K. assamicum* Chowdhury and Tandon described from the Tipam Group (late Miocene) of Assam. Later on, Prakash and Tripathi (1975) and Bande and Srivastava (1988) also recorded it from Assam and West Bengal. As our fossil is also very similar to this species, it has been placed under the same species.

Kayea, a tropical genus of small to medium trees, occurs in South and Southeast Asia. Five species are found in India and Myanmar. In India, they are found in Assam, Sikkim and Andamans, especially in submontane forests (Tandon and Purkayastha, 1958).

Family **Dipterocarpaceae** Blume, 1825
Genus ***Dipterocarpoxylon*** (Holden) Den Berger, 1927

Dipterocarpoxylon nalagarhense Prakash, 1975
(Pl. II, figs. A-G)

Description: Wood diffuse porous. Growth rings indistinct. Vessels round to oval, mostly medium to large, t.d. 104–209 µm, r.d. 172–330 µm, majority solitary, evenly distributed, 6–9 per sq mm, tylosed; vessel elements 164–282 µm in length with horizontal to oblique ends; perforation plates simple; intervessel pits bordered, alternate, 6–7 µm in size with lenticular apertures. Tracheids vasicentric, intermixed with parenchyma to form a thin sheath around vessels. Axial parenchyma both paratracheal and apotracheal; paratracheal scanty to vasicentric, apotracheal diffuse and in the form short broken tangential bands enclosing gum canals; cells 26–48 µm in width and 96–178 µm in length. Rays 1–10 seriate, 5–6 per mm; uniseriate rays rare, made up of upright cells only, 13–24 µm in width and 4–7 cells or 157–271 µm high, multiseriate rays made up of procumbent cells in the median portion and 1–5 rows of upright cells at the margins, 32–150 µm in width and 8–38 cells or 98–971 µm high; sheath cells occasionally present; procumbent cells 10–16 µm in tangential height and 30–81 µm in radial length, upright cells 38–59 µm in tangential height and 15–47 µm in radial length; ray tissue heterogeneous. Fibres thick walled, polygonal in cross section, non septate, 11–15 µm in width. Gum canals normal,

EXPLANATION OF PLATE I

Kayeoxylon assamicum Chowdhury & Tandon
A) Cross section (CS) showing parenchyma pattern and vessel distribution; B) CS enlarged to show banded parenchyma and shape and size of the vessels; C) Tangential longitudinal section (TLS) showing distribution of rays and simple perforation plates; D) TLS enlarged to show structure of rays; E) Showing vasicentric tracheids; F) Radial longitudinal section (RLS) showing heterogeneous ray tissue.

Plate I

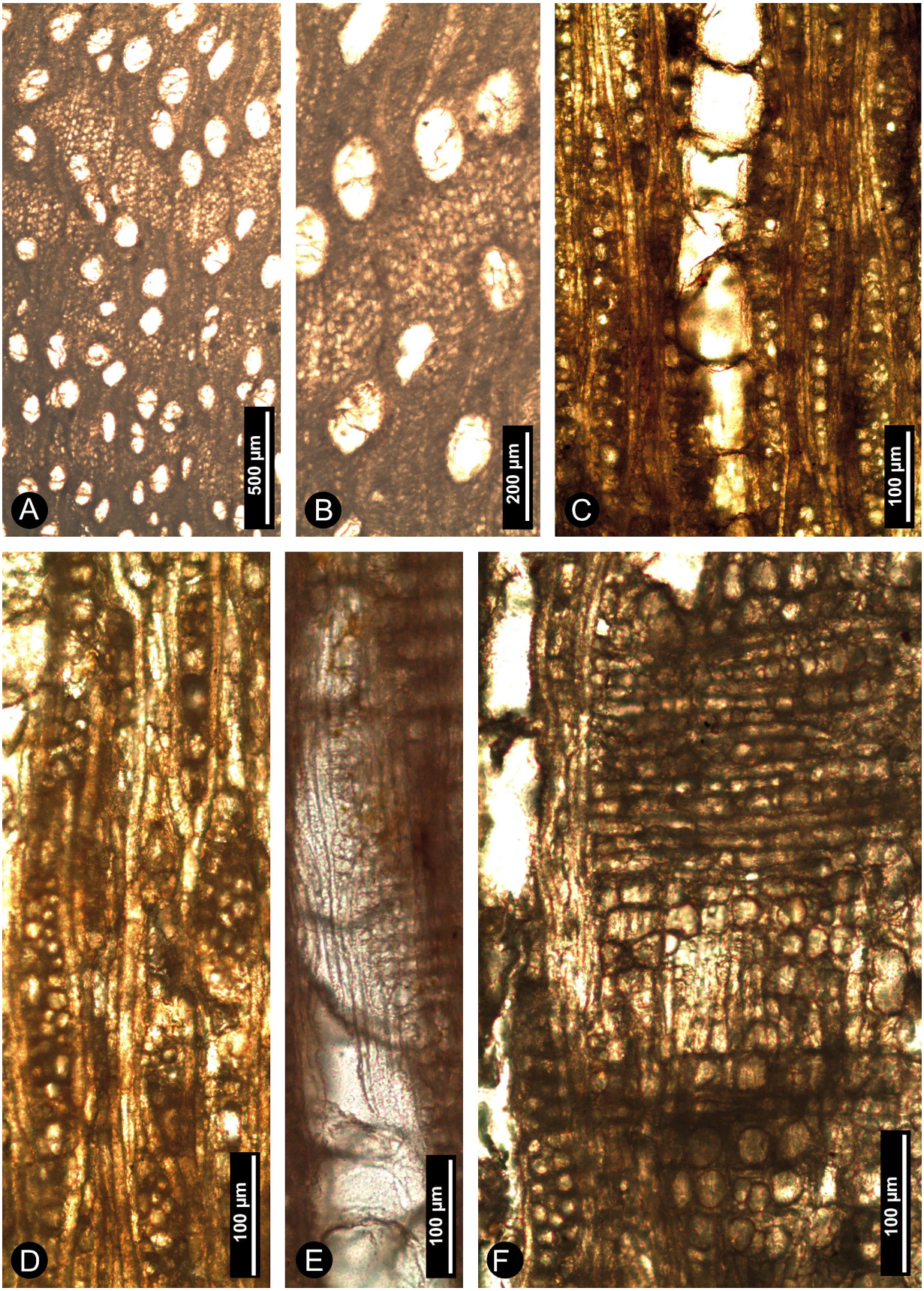


Table 1. Geological succession of Tripura (after Karunakaran, 1974).

Group	Subgroup	Formation	Lithology
Recent		Recent	Alluvium with decomposed vegetable matter
----------	----------	Unconformity	----------
Dupi Tila		Dupi Tila	Early brown to brown buff sandy clays with coarse to gritty ferruginous sandstone
----------	----------	Unconformity	----------
Tipam		Champanagar	Medium to coarse, friable, subarkosic sandstone with abundant lumps of silicified fossil wood
	Tipam Sandstone		----------Contact gradational----------
		Manu Bazar	Fine to medium subarkosic sandstone, including sandy shale, siltstone and sandy mudstone
----------	----------	Contact transitional	----------
	Bokabil		Thinly bedded, repetition of sandstone, siltstone/shale alternations, shales, mudstone and ferruginous sandstone
Surma			---Contact gradational to transitional----------
	Bhuban		Hard, compact, both massive and well bedded sandstone, sandy shale and siltstone repeatedly occurring in space
	Base not seen		

vertical, singly or in rows of 2–4, smaller than vessels, enclosed in parenchyma bands, t.d. 35–58 µm, r.d. 45–110 µm.

Horizon: Tipam Group.

Locality: Laljuri near Kumarghat, Unakoti District, Tripura.

Age: Late Miocene.

Figured specimen: Specimen No. BSIP40423.

*Affinities***:** The important characters of the fossil, namely diffuse porous wood, mostly solitary vessels, simple perforation plates, vasicentric tracheids, vertical gum canals enclosed in parenchyma bands, broad hereterocellular rays and non septate fibres clearly indicate its affinities with Dipterocarpaceae (Pearson and Brown, 1932; Metcalfe and Chalk, 1950; Kribs, 1959; Miles, 1978; Ilic, 1991). Ghosh (1958) provided a key to separate various genera of the family. A perusal of the key indicates that our fossil belongs to *Dipterocarpus* Gaertn. f. on the basis of gum canals in short tangential rows.

Fossil woods resembling *Dipterocarpus* are usually described under *Dipterocarpoxylon* (Hold.) Den Berger (1927). About 17 fossil species of the genus, namely *D. chowdhurii* Ghosh (1956), *D. kalaicharparense* Eyde (1963) and *D. tertiarum* Prakash (Awasthi and Mehrotra, 1993; Mehrotra *et al.*, 2006) from northeast India, *D. malavii* Ghosh and Ghosh (1959) from Kutch (western India), *D. pondicherriense* Awasthi (1974), *D. arcotense* Awasthi (1980) and *Dipterocarpoxylon* sp. (Srivastava, 2001) from south India, *Dipterocarpoxylon* sp. (Rawat, 1964), *D. sivalicus* Prakash (1975), *D. nalagarhense* Prakash (1975), *D. premacrocarpum* Prakash (1975), *D. parabaudii* Prakash (1978), *D. nungarhense* Trivedi and Ahuja (1980), *D. surangei* Prakash (1981), *D. kalagarhensis* Yadav (1989) and *D. jammuense* Guleria *et al.* (2002) from the Siwalik of India and *D. bolpurense* Ghosh and Roy (1979b) from West Bengal were described so far from the Neogene of India. Our fossil shows close resemblance with *D. nalagarhense* and *D. tertiarum* in having broad xylem rays. The fossil is identical to the former, whereas the latter slightly differs from our fossil in having slightly larger vessels (t.d. 135–315 µm, r.d. 150–420 µm) and narrower rays (1–9 seriate).

Dipterocarpus comprises about 69 species distributed in the Indo-Malayan region (Mabberley, 1997). Its 13 species are found in India in the tropical evergreen forests of Assam, Andamans and Western Ghats (Ghosh, 1958; Santapau and Henry, 1973).

Genus ***Shoreoxylon*** Den Berger, 1923

Shoeoxylon evidens Eyde, 1963
(Pl. III, figs. A-G)

Description: Wood diffuse porous. Growth rings indistinct. Vessels round to oval, mostly medium to large, t.d. 78–284 µm, r.d. 212–409 µm, solitary, occasionally in radial pairs, tylosed, 5–6 per sq mm; vessel elements 80–255 µm in length with horizontal to oblique ends; perforation plates simple; intervessel pits bordered, alternate, 5–12 µm in size with lenticular apertures. Vesicentric tracheids present. Axial parenchyma both paratracheal and apotracheal, paratracheal vasicentric to confluent, apotracheal in the form of bands enclosing gum canals; cells 13–34 µm in width and 17–59 µm in length. Rays 8–10 per mm, 1–5 seriate; uniseriates made of upright cells only, 9–16 cells or 507–634 µm high and 21–33 µm in width, multiseriates made up of procumbent cells with extensions of 1–8 rows of upright cells, 21–42 cells or 629 µm to > 1 mm in height and 68–89 µm in width; sheath cells occasionally present; ray tissue heterogeneous; procumbent cells 17–24 µm in tangential height and 43–48 µm in radial length; upright cells 29–45 µm in tangential height and 13–39 µm in radial length. Fibres moderately thick walled, polygonal in cross section, non septate, 9–14 µm in width. Gum canals normal, vertical, in concentric tangential rows, t.d. 49–121 µm and r.d. 90–165 µm.

EXPLANATION OF PLATE II

Dipterocarpoxylon nalagarhense Prakash

A) CS showing distribution of vessels and gum canals; B) CS enlarged to show gum canals in tangential groups enclosed in parenchyma bands and shape and size of the vessels; C) RLS showing heterogeneous ray tissue; D) Showing intervessel pits; E) TLS in low power showing distribution of rays; F) TLS enlarged to show structure of rays; G) Showing vasicentric tracheids.

Plate II

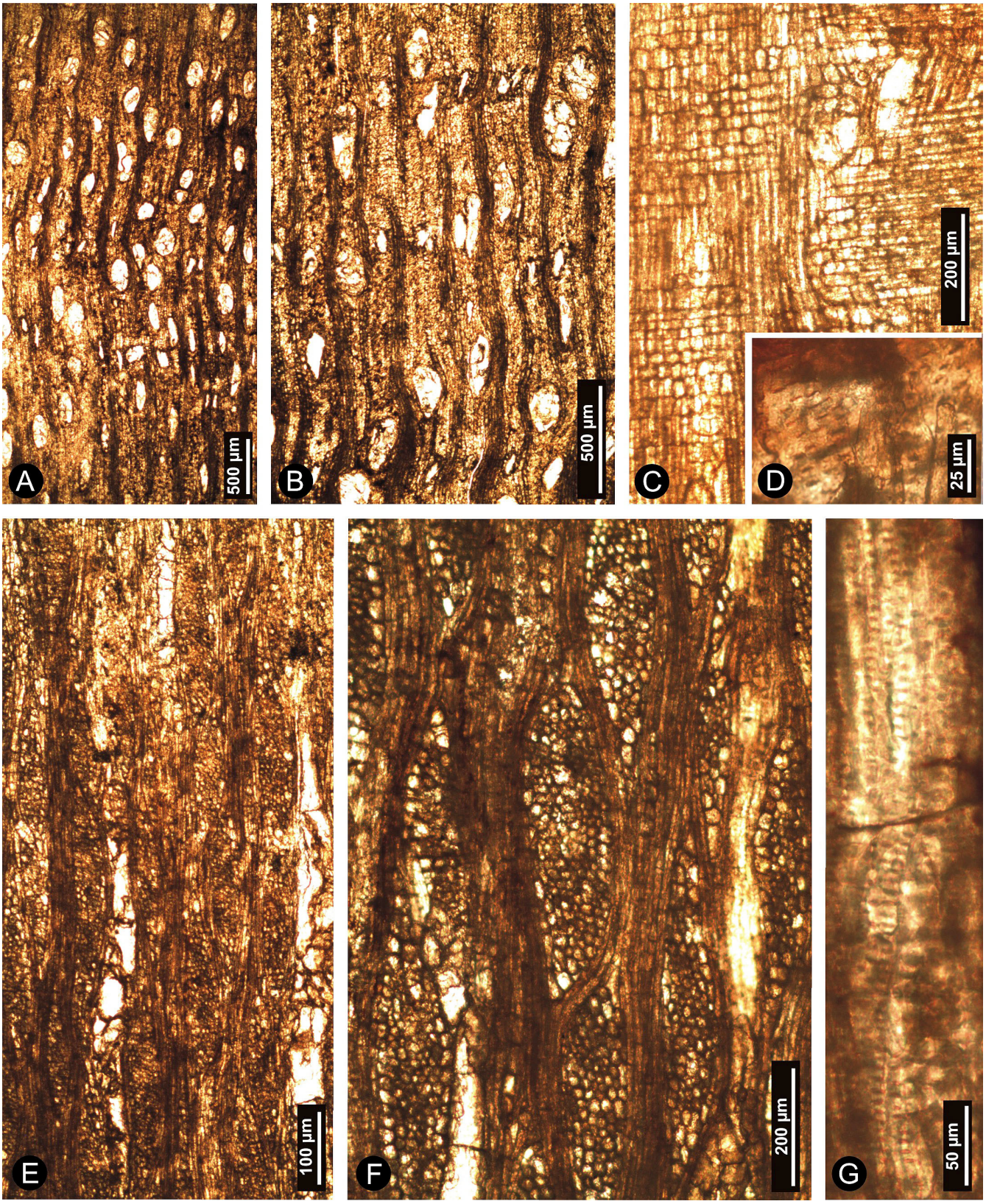


Table 2. Showing distribution of the modern comparable forms of the fossils.

Fossil taxa	Modern comparable forms	Localities	Distribution	References
Anacardiaceae				
Anacardioxylon shardai Prakash and Tripathi	-	Baramura, Kunjaban and Yogendranagar of west Tripura and Mandoli Dhak near Manu Bazar of south Tripura		Sen and Bera (2005)
Glutoxylon burmense (Holden) Chowdhury	*Gluta*	Teliamura of west Tripura	Tropical evergreen and coastal forests of Myanmar and Western Ghats	Ghosh and Taneja (1961); Mehrotra *et al.* (2006)
Combretaceae				
Terminalioxylon siwalicus Prasad	*Terminalia paniculata* Brandis	Baramura, Kunjaban and Yogendranagar of west Tripura	Dry and wet deciduous forests of Western Ghats from Konkan southwards	Sen and Bera (2005)
Dipterocarpaceae				
Anisopteroxylon oblongoides Yadav	*Anisoptera costata* Korth. (synonym *A. oblonga* Dyer)	Baramura, Kunjaban and Yogendranagar of west Tripura	Semi-evergreen and deciduous forests of Myanmar and Malayan Peninsula	Sen and Bera (2005)
Dipterocarpoxylon bolpurense Ghosh and Roy	*Dipterocarpus*	Bishalgarh near Agartala of west Tripura	Tropical evergreen forests of the Indo-Malayan region	Mehrotra and Bhattacharyya (2002)
Dipterocarpoxylon tertiarum Prakash	*Dipterocarpus*	Manughat near Manu Bazar of south Tripura	Tropical evergreen forests of the Indo-Malayan region	Mehrotra *et al.* (2006)
Fabaceae				
Bauhinia deomalica Awasthi and Prakash	*Bauhinia foveolata* Dalzell, *B. malabarica* Roxb. and *B. racemosa* Lam.	Udaipur of south Tripura	Deciduous forests of India	Mehrotra *et al.* (2006)
Bauhinia tertiara Awasthi and Mehrotra	*Bauhinia racemosa* Lam.	Baramura, Kunjaban and Yogendranagar of west Tripura	In dry deciduous forests of central eastern and south India, Myanmar and Sri Lanka	Sen and Bera (2005)
Cassinium tripuranum Acharya and Roy	*Cassia*	Teliamura of west Tripura	Tropical deciduous forests of the Indo-Malayan region	Acharya and Roy (1986)
Cynometroxylon holdenii (Gupta) Prakash and Bande	*Cynometra polyandra* Roxb.	Amarpur of south Tripura	Tropical evergreen forests of Assam and Bangladesh	Awasthi *et al.* (1994)
Millettioxylon bengalensis Ghosh and Roy	*Millettia pulchra* (Bentham) Kurz and *M. pinnata* (L.) Panigrahi (synonym *Pongamia glabra* Vent.)	Teliamura of west Tripura	Tropical dry deciduous and littoral and swamp forests of Assam, Meghalaya and Myanmar	Acharya and Roy (1986)
M. pongamiensis Prakash	*Millettia*	Baramura, Kunjaban and Yogendranagar of west Tripura		Sen and Bera (2005)
Pahudioxylon sahnii Ghosh and Kazmi	*Afzelia-Intsia*	Teliamura of west Tripura	Tropical evergreen and littoral and swamp forests of Tropical Africa and Asia, off shore Islands of East Africa and Madagascar	Ghosh and Kazmi (1961)
Sapindaceae				
Euphorioxylon indicum Awasthi *et al.*	*Dimocarpus longan* Lour. (synonym *Euphoria longana* Lamk.	Baramura, Kunjaban and Yogendranagar of west Tripura	Throughout the Western Ghats from the Konkan southwards extending to Sri Lanka, Assam, southern China, Myanmar and Malaysia	Sen and Bera (2005)

EXPLANATION OF PLATE III

Shoeoxylon evidens Eyde

A) CS showing distribution of vessels and gum canals; B) CS enlarged to show a row of gum canals enclosed in a parenchyma band and shape and size of the vessels; C) TLS showing distribution of rays; D) TLS enlarged to show structure of rays; E) Showing vasicentric tracheids; F) RLS showing heterogeneous ray tissue; G) Showing intervessel pits.

Plate III

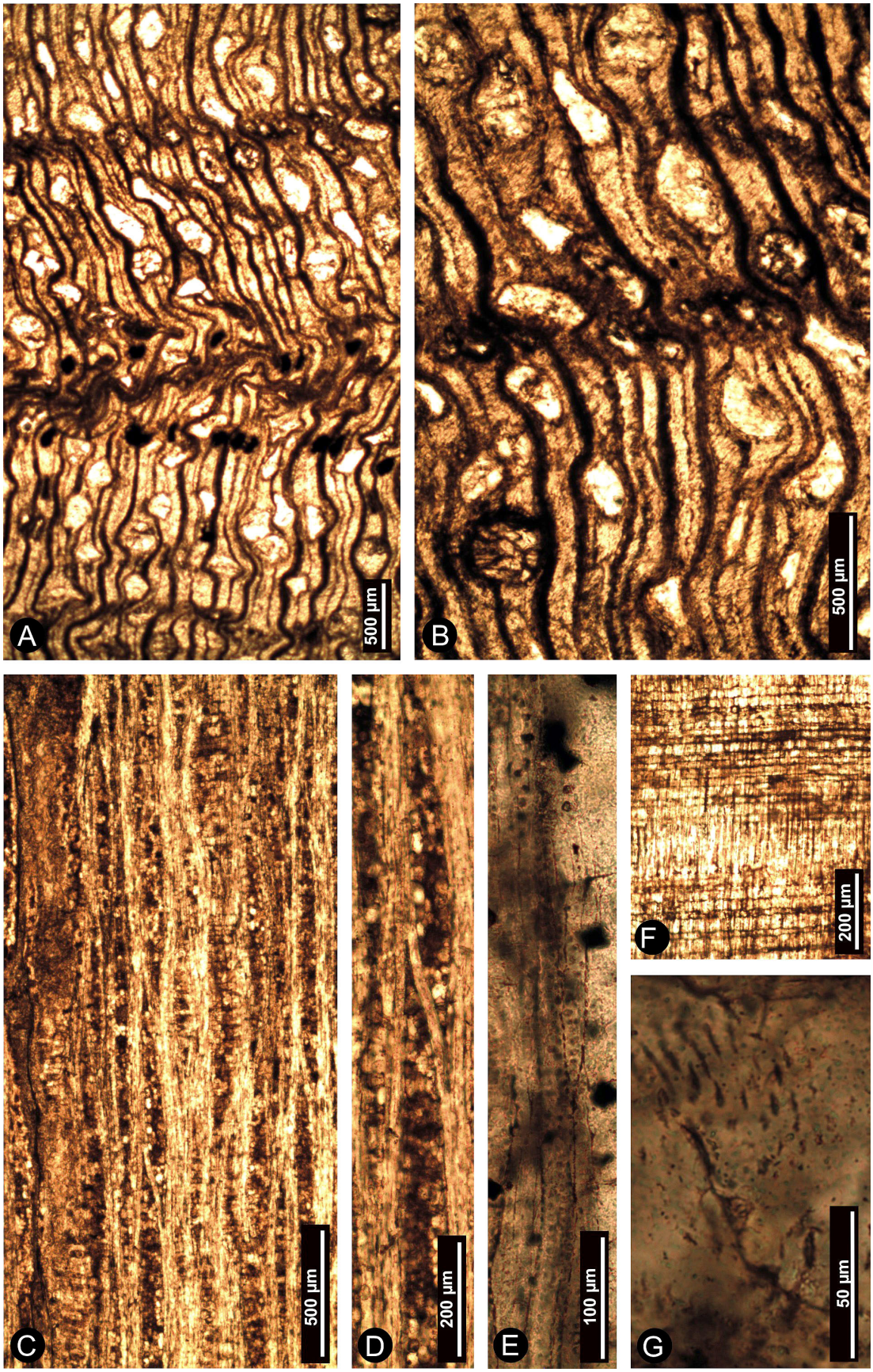


Table 3. Comparison of the modern comparable forms of Tripura assemblage with those of other Miocene flora of India

Tripura assemblage	Flora of western India	Flora of south India	Flora of West Bengal	Flora of northeast India	Siwalik flora
Mangifera	-	+	+	+	-
Gluta	+	+	+	+	+
Kayea	-	+	+	+	+
Terminalia	+	+	+	+	+
Anisoptera	-	-	+	+	+
Dipterocarpus	-	+	+	+	+
Shorea	+	+	+	+	+
Afzelia-Intsia	+	+	+	+	+
Bauhinia	+	+	-	+	+
Cassia	+	+	+	+	+
Cynometra	-	+	+	+	+
Millettia	+	+	+	+	+
Euphoria	-	+	-	+	+

Horizon: Tipam Group.

Locality: Laljuri near Kumarghat, Unakoti District, Tripura.

Age: Late Miocene.

Figured specimen: Specimen No. BSIP40424.

Affinities: The diagnostic characters of the fossil wood are: predominantly solitary vessels, vasicentric tracheids, vertical gum canals, moderately broad rays and non sepatate fibres. These features collectively indicate its affinities with Dipterocarpaceae (Pearson and Brown, 1932; Metcalfe and Chalk, 1950; Kribs, 1959; Miles, 1978; Ilic, 1991). Ghosh (1958) provided a key to separate various genera of the family and a perusal of the key indicates that our fossil is close to *Parashorea* Kurz, *Pentacme* A. DC. and *Shorea* Roxb. ex C.F. Gaertn. due to concentric rows of gum canals, large vessels and vasicentric to confluent parenchyma.

Schweitzer (1958) named the fossil woods of Dipterocarpaceae, which possess gum canals in concentric bands, as *Dryobalanoxylon* Den Berger (1923) and *Shoreoxylon* Den Berger (1923). The former includes *Dryobalanops* possessing fibretracheids, while the latter comprises genera of the Shoreae group having only libriform fibres. Our fossil lacking fibretracheids and having libriform fibres has been included under *Shoreoxylon* instituted to include *Shorea* and allied forms. About 30 species of the genus known so far were enlisted by many workers (Prakash, 1973; Awasthi, 1974; Prasad and Prakash, 1988; Bera and Banerjee, 2001). Total 11 species of this genus known from India are: *Shoreoxylon arcotense* Awasthi (1974), *S. cuddalorense* Gurusamy and Kumarasamy (2007), *S. indicum* Awasthi (1974) and *S. krauseli* Ramanujam and Rao (1969) from the Cuddalore Sandstone of south India, *S. burmense* Prakash *et al*. (1994), *S. deomaliense* Prakash and Awasthi (1971), *S. evidens* Eyde (1963) and *S. tipamense* Prakash and Awasthi (1970) from the Mio-Pliocene sediments of northeast India, *S. robustoides* Roy and Ghosh (1981) from the Tertiary of West Bengal and *S. ornatum* Bande and Prakash (1980) and *S. siwalicus* Prasad and Prakash (1988) from the Lower Siwalik of Kalagarh, Uttarakhand. Our fossil in a combination of characters, especially in having abundant paratracheal parenchyma, 5–6 vessels per square mm and 1–5 seriate heterocellular rays indicates its best resemblance with *S. evidens*.

Family **Fabaceae Lindley, 1836**

Genus ***Cynometroxylon*** Chowdhury and Ghosh, 1946

Cynometroxylon holdenii (Gupta) Prakash and Bande, 1980

(Pl. IV, figs. A-F)

Description: Wood diffuse porous. Growth rings absent. Vessels round to oval, mostly medium to large, t.d. 63–212 µm, r.d. 91–248 µm, solitary and in radial multiples of 2-3, 7–9 per sq mm, filled with black contents; vessel elements 214–397 µm in length with horizontal to oblique ends; perforation plates simple; intervessel pits bordered, alternate, 5–7 µm in size, vestured. Axial parenchyma paratracheal in the form of continuous concentric straight to wavy bands alternating with fibre bands and 4–5 per mm; cells 15–17 µm in width and 13–26 µm in length. Rays 7–9 per mm, 1–4 seriate, uniseriates made of procumbent cells only, 16–19 µm in width and 9–11 cells or 289–330 µm high, multiseriates made of procumbent cells in the central portion with 1–4 rows of upright cells at the margins, 59–70 µm in width and 22–25 cells or 626–872 µm high; procumbent cells 23–28 µm in tangential height and 61–77 µm in radial length; upright cells 67–69 µm in tangential height and 51–62 µm in radial length; ray tissue weakly heterogeneous. Fibres moderately thick walled, polygonal in cross section, non septate, 9–10 µm in width.

Horizon: Tipam Group.

Locality: Laljuri near Kumarghat, Unakoti District, Tripura.

Age: Late Miocene.

Figured specimen: Specimen No. BSIP40425.

Affinities: The diagnostic features of the fossil wood such as: diffuse porous wood, simple perforation plates, vestured intervessel pits, continuous, concentric bands of paratracheal parenchyma, 1–4 seriate homo to heterocellular rays and non septate fibres indicate its best resemblance with *Cynometra* Linn. of the Fabaceae (Pearson and Brown, 1932; Metcalfe and Chalk, 1950; Kribs, 1959; Miles, 1978; Ilic, 1991). The other closely allied genera *Dialium* L., *Millettia* Wight and Arn. and *Pongamia* Vent. can be differentiated from it in having storied elements (Ramesh Rao *et al.*, 1972). Among various species of *Cynometra*, the fossil is close to *C. polyandra* (Roxb.) Harms and *C. ramiflora* L. (Ramesh Rao *et al.*, 1972).

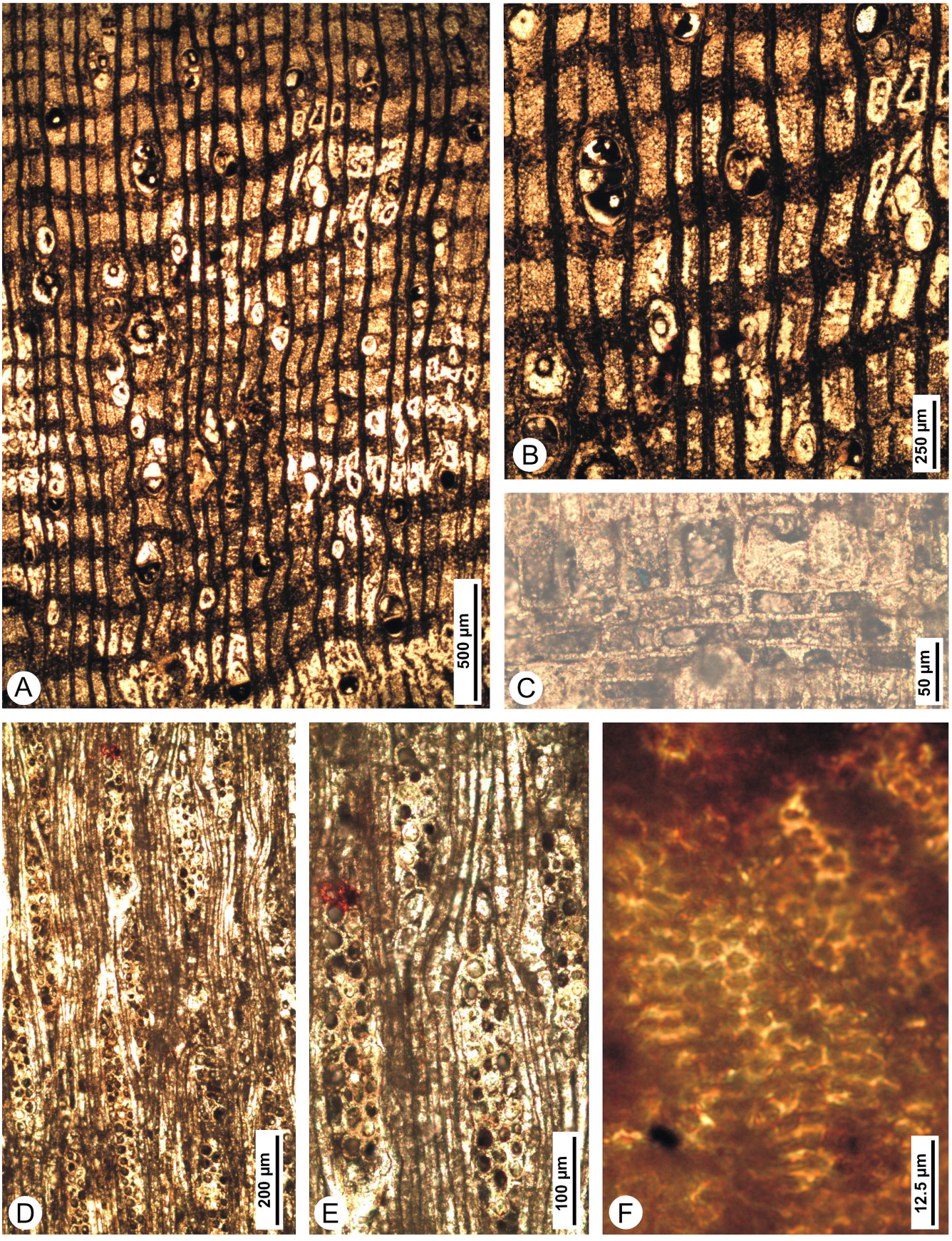
The fossil woods resembling *Cynometra* are generally described under the genus *Cynometroxylon* instituted by Chowdhury and Ghosh (1946). Prakash and Bande (1980) critically reviewed various species of this fossil genus described from all over the world before 1980 and placed them under *C. indicum* (Gupta) Prakash and Bande. The other two known species of the genus are *C. parainaequifolium* Prakash (1979) described from the Tertiary of Thailand and *C. tertiarum* Awasthi and Mehrotra (1997) described from the Neogene of

EXPLANATION OF PLATE IV

Cynometroxylon holdenii (Gupta) Prakash and Bande

A) CS showing distribution of vessels and bands of parenchyma; B) CS enlarged to show parenchyma bands alternating with fibre bands; C) RLS showing weakly heterogeneous ray tissue; D) TLS showing distribution of rays; E) TLS enlarged to show structure of rays; F) Showing vestured intervessel pits.

Plate IV



Tirap District, Arunachal Pradesh. Our fossil shows very close resemblance with *C. holdenii* (Gupta) Prakash and Bande and has therefore been assigned to this species.

The genus *Cynometra* consists of about 60 species of evergreen trees or shrubs distributed in the tropics of Indo-Malayan region, Philippines, Australia, Pacific Islands, Mexico, Brazil and Africa (Ramesh Rao *et al.*, 1972; Mabberley, 1997). *C. polyandra* is found in Assam, Meghalaya and Bangladesh, while *C. ramiflora* occurs in tidal forests of Sunderbans, southern India, Andamans, Myanmar and Sri Lanka.

Genus ***Millettioxylon*** Awasthi, 1967

Millettioxylon indicum Awasthi, 1967
(Pl. V, figs. A-G)

Description: Wood diffuse porous. Growth rings not obseved. Vessels round to oval, sometimes elongated, mostly medium to large, t.d. 74–160 µm, r.d. 83–274 µm, solitary and in radial multiples of 2-3, 7–9 per sq mm; tyloses absent,; vessel elements 140–237 µm in length with horizontal to oblique ends, storied at places; perforation plates simple; intervessel pits bordered, alternate, 3–6 µm in size, vestured. Axial parenchyma paratracheal in the form of continuous concentric straight to wavy bands (up to 8 cells), bands broader than alternating fibre bands and about 3 per mm; strands occasionally storied; cells 15–17 µm in width and 57–88 µm in length. Rays 7–9 per mm, 1–3 (mostly bi) seriate, uniseriates rare, made of procumbent cells only, 15–34 µm in width and 10–19 cells or 216–373 µm high, occasionally storied; ray cells 13–19 µm in tangential height and 32–39 µm in radial length; ray tissue homogeneous. Fibres thick walled, polygonal in cross section, non septate, 7–10 µm in width. Ripple marks present due to storied nature of rays, vessel elements and parenchyma strands.

Horizon: Tipam Group.

Locality: Laljuri near Kumarghat, Unakoti District, Tripura.

Age: Late Miocene.

Figured specimen: Specimen No. BSIP40426.

Affinities: The important characters of the fossil wood viz., diffuse porous wood, simple perforation plates, vestured intervessel pits, paratracheal concentric bands of parenchyma, thin and storied rays and non septate fibres indicate its affinities with Fabaceae (Pearson and Brown, 1932; Metcalfe and Chalk, 1950; Kribs, 1959; Miles, 1978; Ilic, 1991). Ramesh Rao *et al.* (1972) provided six tables to identify various genera of the family. A perusal of these tables indicates that the present fossil is closely comparable to *Millettia leucantha* Kurz (synonym *M. pendula* Baker) and *M. pinnata* (L.) Panigrahi (synonym *Pongamia glabra* Vent.)

The fossil woods comparable to *Millettia* Wight and Arn. are generally described as *Millettioxylon* instituted by Awasthi (1967). Six species of the genus, namely *M. bengalensis* Ghosh and Roy (1979a), *M. embergeri* Lemoigne (1978), *M. indicum* Awasthi (1967), *M. kalagarhensis* (Trivedi and Mishra) Guleria (1984), *M. palaeopulchra* Lakhanpal *et al.* (1981) and *M. pongamiensis* Prakash (1975) are known so far from various parts of the world. The present fossil is identical to *M. indicum* described from the Cuddalore Sandstone of south India. The other species are different from our fossil mainly in having narrower bands of parenchyma.

A few years back Sen and Bera (2005) reported *M. pongamiensis* Prakash from West Tripura. As their fossil does not possess storied rays, an important feature of the species, its inclusion in the above species is not justified. Moreover, neither parenchyma strands nor vessel elements show any storied tendency in their fossil, therefore, its resemblance with *Millettia* appears doubtful.

Millettia consists of about 90 species of extant trees, shrubs and woody climbers found in the warmer regions of Africa, Asia and Australia. About 30 of its species are reported to occur in the Indian subcontinent, especially in Myanmar. *Millettia leucantha* is distributed in the drier forests of Myanmar, Pegu Yoma, Shweba, Upper Chindwin and Tenasserim, while *M. pinnata* is commonly found throughout India and Myanmar in the tidal and beach forests.

DISCUSSION

Nearest Living Relative (NLR) is the best method for the reconstruction of the palaeoclimate on the basis of fossil woods. The modern comparable forms of the present assemblage are *Kayea* of the Calophyllaceae, *Dipterocarpus* and *Shorea* of the Dipterocarpaceae and *Cynometra polyandra* and *C. ramiflora* and *Millettia leucantha* and *M. pinnata* of the Fabaceae. Distribution of these forms, along with the already known taxa from the Tipam Group of Tripura is presented in Table 2. A perusal of the table indicates that most of the forms are growing in tropical evergreen to deciduous forests (Champion and Seth, 1968) suggesting a warm and humid climate in the region during the period of deposition. The occurrence of *Gluta*, *Afzelia-Intsia*, *Cynometra ramiflora* and *Millettia pinnata* indicates coastal conditions in the region. Moreover, all the fossil woods in the present assemblage are diffuse porous indicating tropical conditions with little seasonality in temperature. Taxa of the fossil assemblage possess generally large vessels with simple perforations which indicate high precipitation. According to Wolfe and Upchurch Jr. (1987), mega thermal woods have high amount of paratracheal parenchyma. As most of the taxa in this assemblage have this type of parenchyma, their presence indicates high temperature. The presence of homocellular and storied rays in some of the taxa supports the above view (Woodcock and Ignas, 1994).

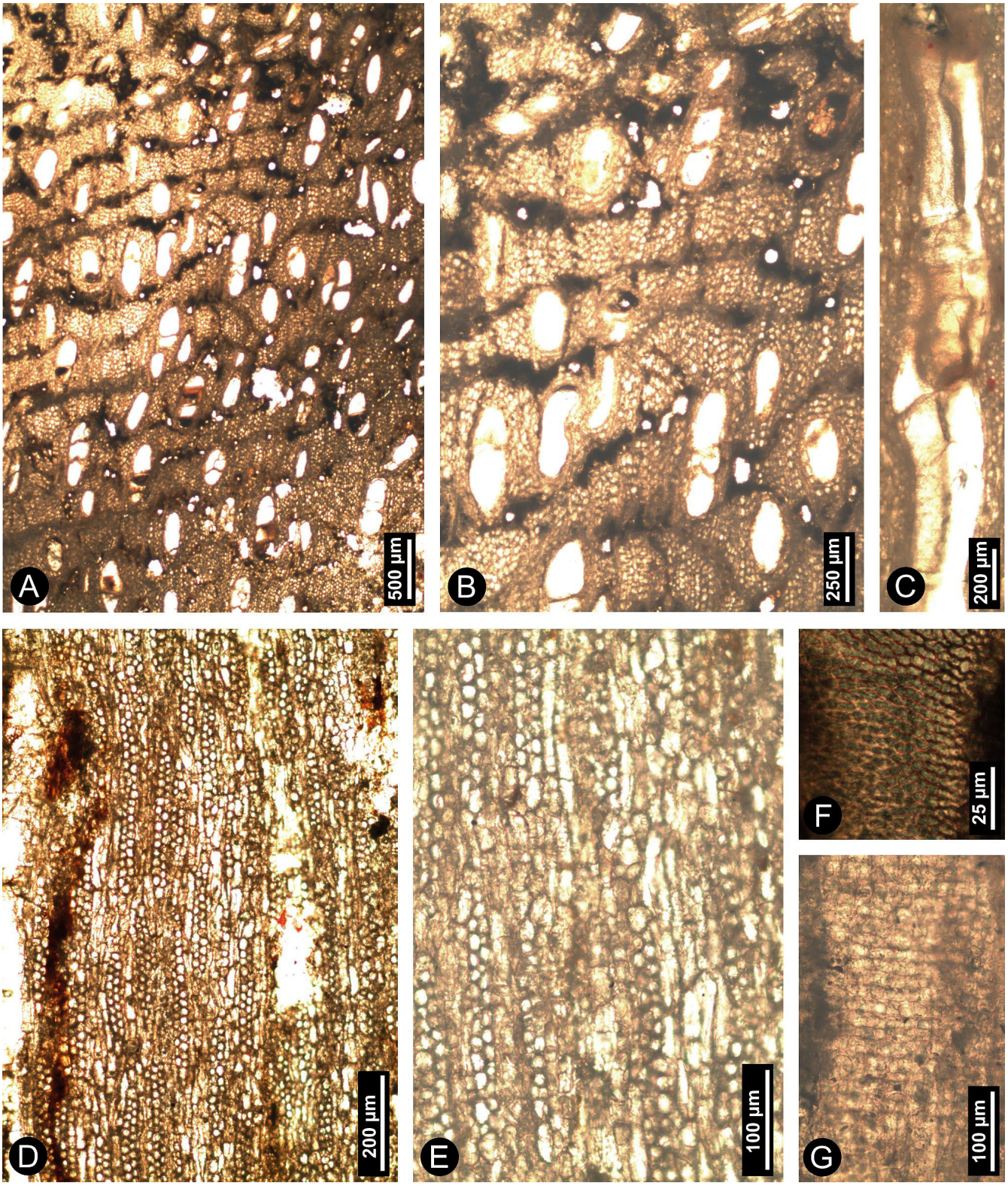
Most of the taxa present in the fossil flora are also found in other Neogene assemblages known from India. This shows that the Neogene flora was more or less similar throughout India and same climatic conditions prevailed during the period (Table 3).

EXPLANATION OF PLATE V

Millettioxylon indicum Awasthi

A) CS showing distribution of vessels and parenchyma pattern; B) CS enlarged to show parenchyma bands alternating with fibre bands and shape and size of the vessels; C) TLS showing storied vessel elements; D) TLS showing distribution of rays; E) TLS showing storied rays; F) Showing vestured intervessel pits; G) RLS showing homogeneous ray tissue.

Plate V



ACKNOWLEDGEMENTS

The authors are thankful to the Director, Birbal Sahni Institute of Palaeosciences, Lucknow for infrastructure facilities and permission to publish the present work. One of us (NM) is thankful to the Council of Scientific and Industrial Research (C.S.I.R.) Human Resource Development Group (H.R.D.G), New Delhi for providing the financial assistance for this work. The authors are also thankful to Baharul Islam Majumdar, Joint Director of Agriculture (Research), Department of Agriculture, Government of Tripura and his departmental members for their help and support during the field trip in Tripura.

REFERENCES

Acharya, S. and Roy, S. K. 1986. Fossil wood of Leguminosae from the Tertiary of Tripura, India. *Burdwan University Science Journal*, **3**: 127–132.

Awasthi, N. 1967. Fossil wood resembling that of *Millettia* from the Tertiary of south India. *Current Science*, **36**: 180–181.

Awasthi, N. 1974. Occurrence of some dipterocarpaceous woods in the Cuddalore Series of south India. *Palaeobotanist*, **21**: 339–351.

Awasthi, N. 1980. Two new dipterocarpaceous woods from the Cuddalore Series near Pondicherry. *Palaeobotanist*, **26**: 248–256.

Awasthi, N. and Mehrotra, R. C. 1993. Further contribution to the Neogene flora of northeast India and significance of the occurrence of African element. *Geophytology*, **23**: 81–92.

Awasthi, N. and Mehrotra, R. C. 1997. Some fossil dicotyledonous woods from the Neogene of Arunachal Pradesh, India. *Palaeontographica*, **245B**: 109–121.

Awasthi, N., Mehrotra, R. C. and Bhattacharyya, A. 1994. Fossil wood of *Cynometra* from the Neogene of Tripura. *Geophytology*, **23**: 291–293.

Bande, M. B. and Srivastava, G. P. 1988. Fossil woods of Guttiferae (*Kayea*) and Lauraceae from the Tertiary of West Bengal. *Geophytology*, **18**: 217–218.

Bera, S. and Banerjee, M. 2001. Petrified wood remains from Neogene sediments of the Bengal basin, India, with remarks on palaeoecology. *Palaeontographica*, **260B**: 167–199.

Champion, H. and Seth, S. K. 1968. *The forest types of India.* Manager of Publications, Delhi.

Chowdhury, K. A. and Ghosh, S. S. 1946. On the anatomy of *Cynometroxylon indicum* gen. et sp. nov. – a fossil dicotyledonous wood from Nailalung, Assam. *Proceedings of the National Institute of Sciences of India*, **12:** 435–447.

Chowdhury, K. A. and Tandon, K. N. 1949. *Kayeoxylon assamicum* gen. et sp. nov., a fossil dicotyledonous wood from Assam. *Proceedings of the National Institute of Sciences of India*, **15:** 59–65.

Den Berger, L. G. 1923. Fossiele houtsoorten uit het Tertiair van Zuid-Sumatra. *Verhandelingen-Koninklijke Neder-lands Geologisch en Mijnbouwkundig Genootschap Geological Series* **7**: 143–148.

Den Berger, L. G. 1927. Unterscheidungmerkmale von rezenten und fossilen Dipterocarpaceen gattungen. *Bull Du Jardin Botanique de Buintenzrg*, **3**: 495–498.

Eyde, R. H. 1963. A *Shoreoxylon* and two other Tertiary woods from the Garo Hills, Assam. *Palaeobotanist*, **11**: 115–121.

Ghosh, P. K. and Roy, S. K. 1979a. A new species of *Millettia* from the Tertiary of West Bengal, India. *Current Science*, **48**: 165–166.

Ghosh, P. K. and Roy, S. K. 1979b. *Dipterocarpoxylon bolpurense* sp.nov., a fossil wood of Dipterocarpaceae from the Tertiary of West Bengal, India. *Current Science*, **48**: 495–496.

Ghosh, S. S. 1956. On a fossil wood belonging to the genus *Dipterocarpus*. *Science & Culture*, **21**: 691–692.

Ghosh, S. S. 1958. Family Dipterocarpaceae, p. 98–107. In: *Indian Woods-I* (Eds. Chowdhury, K.A. and Ghosh, S.S.), The Manager of Publications, Delhi.

Ghosh, S. S. and Ghosh, A. K. 1959. *Dipterocarpoxylon malvii* sp. nov. — a new fossil record from the Pliocene of Kutch. *Science & Culture*, **25**: 328–332.

Ghosh, S. S. and Kazmi, M. H. 1961. *Pahudioxylon sahnii* sp. nov., a new fossil record from the Miocene (?) of Tripura. *Science & Culture*, **27**: 96–98.

Ghosh, S. S. and Taneja, K. K. 1961. Further record of *Glutoxylon* from the Miocene (?) of Tripura. *Science & Culture*, **27**: 581–582.

Guleria, J. S. 1984. Leguminous woods from the Tertiary of District Kachchh, Gujarat, western India. *Palaeobotanist*, **31**: 238–254.

Guleria, J. S., Gupta, S. S. and Srivastava, R. 2002. Fossil woods from Upper Tertiary sediments of Jammu region (Jammu and Kashmir) north-west India and their significance. *Palaeobotanist*, **50**: 225–246.

Gurusamy, V. and Kumarsamy D. 2007. A new species of *Shoreoxylon* from the Cuddalore series, Tamil Nadu, India. *Plant Archives*, **7**: 165–167.

IAWA 1989. IAWA list of microscopic features for hardwood identification. IAWA New Series, **10:** 219–332.

Ilic, J. 1991. *CSIRO Atlas of hard woods*. Springer-Verlag, Berlin.

Karunakaran, C. 1974. Geology and mineral resources of the states of India. Part IV – Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram, Nagaland and Tripura. *Geological Survey of India Miscellaneous Publication*, No 30**:** 1–124.

Kribs, D. A. 1959. *Commercial foreign woods on the American market*. Pennsylvania State University, Pennsylvania.

Lakhanpal, R. N., Prakash, U. and Awasthi N. 1981. Some more dicotyledonous woods from the Tertiary of Deomali, Arunachal Pradesh, India. *Palaeobotanist*, **27**: 232– 251.

Lemoigne, Y. 1978. Flores tertiaires de la haute vallée de l' Omo (Ethiopie). *Palaeontographica*, **165B**: 89–157.

Mabberley, D. J. 1997. *The plant book. A portable dictionary of vascular plants.* Cambridge University Press, Cambridge.

Mehrotra, R. C. and Bhattacharyya, A. 2002. Wood of *Dipterocarpus* from a new locality of the Champanagar Formation of Tripura, India. *Palaeobotanist*, 51: 123–127.

Mehrotra, R. C., Bhattacharyya, A. and Shah, S. K. 2006. Petrified Neogene woods of Tripura. *Palaeobotanist*, **55**: 67–76.

Metcalfe, C. R. and Chalk, L. 1950. *Anatomy of the dicotyledons, I-II.* Clarendon Press, Oxford.

Miles, A. 1978. *Photomicrographs of world woods*. Building Research Establishment Report, London.

Pearson, R. S. and Brown, H. P. 1932. *Commercial Timbers of India, I-II.* Government of India Central Publication Branch, Calcutta.

Prakash, U. 1973. Fossil woods from the Tertiary of Burma. *Palaeobotanist*, **20**: 48–70.

Prakash, U. 1975. Fossil woods from the Siwalik beds of Himachal Pradesh, India. *Palaeobotanist*, **22**: 192–210.

Prakash, U. 1978. Fossil woods from the Lower Siwalik beds of Uttar Pradesh, India. *Palaeobotanist*, **25**: 376–392.

Prakash, U. 1979. Fossil dicotyledonous woods from the Tertiary of Thailand. *Palaeobotanist*, **26**: 50–62.

Prakash, U. 1980. Fossil woods from the Tertiary of West Bengal. *Geophytology*, **10**: 146–157.

Prakash, U. 1981. Further occurrence of fossil wood from the Lower Siwalik beds of Uttar Pradesh, India. *Palaeobotanist*, **28-29**: 374–388.

Prakash, U. and Awasthi, N. 1970. Fossil woods from the Tertiary of eastern India: I. *Palaeobotanist*, **18**: 32– 44.

Prakash, U. and Awasthi, N. 1971. Fossil woods from the Tertiary of eastern India: II. *Palaeobotanist*, **18**: 219–225.

Prakash, U. and Bande, M. B. 1980. Some more fossil woods from the Tertiary of Burma. *Palaeobotanist*, **26**: 261–278.

Prakash, U. and Tripathi, P. P. 1975. Fossil dicotyledonous wood from the Tertiary of eastern India. *Palaeobotanist*, **22**: 51– 62.

Prakash, U., Vaidyanathan, L. and Tripathi, P. P. 1994. Plant remains from the Tipam Sandstones of northeast India with remarks on the palaeoecology of the region during the Miocene. *Palaeontographica* **231B**: 113–146.

Prasad, M. and Prakash, U. 1988. Occurrence of Malayan dipterocarps in the Siwalik sediments of Uttar Pradesh. *Geophytology*, **17**: 245–255.

Ramanujam, C. G. K. and Rao, M. R. R. 1969. *Shoreoxylon*, *S. kraeuseli* sp. nov. a new dipterocarpaceous wood from the Cuddalore Series of South India. *Current Science*, **36**: 439-441.

Ramesh Rao, K., Purkayastha, S. K., Shahi, R., Juneja, K. B. S., Negi, B. S. and Kazmi, M. H. 1972. Family Leguminosae, p. 264–323. In:

Indian Woods-III (Eds. Ramesh Rao, K. and Purkayastha, S.K.), The Manager of Publications, Delhi.

Rawat, M. S. 1964. A new record of *Dipterocarpoxylon* from Siwalik Formation of Uttar Pradesh. *Science & Culture*, **30**: 337–338.

Roy, S. K. and Ghosh, P. K. 1981. *Shoreoxylon robustoides* sp. nov., a new fossil wood of Dipterocarpaceae from the Tertiary of West Bengal, India. *Journal of the Indian Botanical Society*, **60**: 307–311.

Santapau, H. and Henry, A.N. 1973. *A dictionary of the flowering plants in India*. Publication & Information Directorate, New Delhi.

Schweitzer, H. J. 1958. Die fossilen Dipterocarpaceen-Hölzer. *Palaeontographica*, **105B**: 1–66.

Sen, I. and Bera, S. 2005. Petrified wood remains from the Neogene of Tripura. *Geophytology*, **35**: 65–73.

Srivastava, R. 2001. Angiospermous fossil woods from lignite beds of Warkalli Formation, Kerala Coast, India. *Geological Survey of India Special Publication*, **54**: 135–144.

Tandon, K. N. and Purkayastha, S. K. 1958. Family Guttiferae, p. 69–85. In: *Indian Woods-I* (Eds. Chowdhury, K.A. and Ghosh, S.S.), The Manager of Publications, Delhi.

Trivedi, B. S. and Ahuja, M. 1980. *Dipterocarpoxylon nungarhense* n. sp. from Kalagarh (Bijnor District), India. *Palaeobotanist,* **26**: 221–225.

Wheeler, E. A., Pearson, R. G., La Pasha, C. A., Zack, T. and Hatley, W. 1986. Computer aided wood identification. *North Carolina Agricultural Research Service Bulletin*, **474**: 1–96.

Wolfe, J. A. and Upchurch Jr., G. R. 1987. North American nonmarine climates and vegetation during the Late Cretaceous. *Palaeogeography, Paleoclimatology, Palaeoecology*, **61**: 33–77.

Woodcock, D. W. and Ignas, C. M. 1994. Prevalence of wood characters in eastern North America: What characters are most promising for interpreting climates from fossil wood. *American Journal of Botany*, **81**: 1243–1251.

Yadav, R. R. 1989. Some more fossil woods from the Lower Siwalik sediments of Kalagarh, Uttar Pradesh and Nalagarh, Himachal Pradesh. *Palaeobotanist*, **37**: 52–62.

Manuscript received December 2015

Revised Manuscript accepted October 2016